

# Efficiency of high-intensity interval training on $VO_2$ max vital capacity and body composition in male swimmers

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## Abstract

**Background and Study Aim** Core muscles are a key part of any swimmer's training, and using a high-intensity interval training approach can help support an athlete's performance. The aim of this study was to evaluate the effectiveness of a six-week core muscle high-intensity interval training (CM-HIIT) regimen on  $VO_2$ max, vital capacity, and body composition in male swimmers.

**Material and Methods** Twenty male swimmers with similar 50-meter swimming performances participated in the study. They were randomly assigned to two groups. The experimental group ( $n = 10$ ; age =  $21.4 \pm 0.84$  years, BMI =  $25.19 \pm 5.00$  kg/m<sup>2</sup>) performed CM-HIIT three days per week. The control group ( $n = 10$ ; age =  $20.4 \pm 0.70$  years, BMI =  $24.99 \pm 6.42$  kg/m<sup>2</sup>) followed their usual swimming training program.  $VO_2$ max was assessed using the YMCA submaximal cycle test, vital capacity was measured with a spirometer, and body composition was evaluated using bioelectrical impedance analysis.

**Results** After six weeks,  $VO_2$ max significantly increased compared to baseline ( $p < 0.05$ ). Vital capacity also showed a significant improvement, with higher values observed after six weeks ( $p < 0.05$ ). Body composition improved, with significant reductions in body fat percentage and fat mass, while muscle mass increased in the experimental group ( $p < 0.05$ ). Additionally, Max HR significantly decreased after four and six weeks, whereas resting HR showed no significant changes. In the control group, body fat percentage and fat mass significantly decreased, but no significant differences were observed in body weight, BMI, or muscle mass.

**Conclusions** Core muscle high-intensity interval training induces physiological adaptations, enhances cardiovascular fitness, and improves body composition in trained swimmers, all of which are critical for swimming performance. However, coaches and trainers must carefully monitor training intensity to optimize oxygen uptake while ensuring safety and performance efficiency.

**Keywords:** HIIT, aerobic capacity, lung function, core muscle exercise, swimming

## Introduction

Currently, there are various training methods for swimmers to improve and develop their physical fitness, especially in terms of their aerobic capacity ( $VO_2$ max) and body composition, which are no less important indicators than other fitness factors that support swimmers in achieving their optimal sports performance throughout the competition [1, 2]. Swimming competitions are divided into three distances: short-distance (50–100 m), middle-distance (200–400 m), and long-distance (800–1500

m) events [3, 4]. When athletes start the competition after the starting signal, they dive into the water and swim at their maximum intensity according to their training level [5, 6].

One such training method is high-intensity interval training (HIIT), a form of training that involves intense physical exertion. It is characterized by intermittent bouts of exercise performed at a training intensity close to the maximum rate or at a level not lower than 90% of  $VO_2$ max or at 85–95% of maximum heart rate for short periods of 10–30 seconds, alternated with rest periods or training at a low-intensity level [7, 8, 9, 10, 11].

In recent years, the HIIT protocol has gained popularity and has been investigated as an alternative

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training method that can improve and develop aerobic capacity, as measured by maximum oxygen uptake ( $VO_2\text{max}$ ), cardiorespiratory endurance, and body composition [12, 13, 14, 15, 16]. Many previous studies have reported that performing HIIT two to three days per week for four to eight weeks can improve aerobic performance and body composition in handball, field hockey, and football athletes more effectively than conventional training [17, 18, 19, 20]. In addition, it was found that swimmers who performed short bursts of high-intensity interval training (HIIT) at an intensity of at least 90% of  $VO_2\text{max}$  in conjunction with a regular training program three days per week experienced a 9.6% greater increase in  $VO_2\text{max}$  than a control group that followed conventional swimming training alone [4, 9, 21]. Similarly, previous studies have shown that core muscle training in male swimmers, including plank, side plank, bridging, bird dog, dead bug, leg drop, reverse arm reverse leg, reverse crunch, back bridge, and V-sitting, three times per week for six to eight weeks, can improve swimming performance and reduce swimming time more effectively than a control group that trained according to the usual program [22, 23].

From the above studies, it can be seen that  $VO_2\text{max}$  is an important factor in swimming competitions at all distances [24, 1, 25]. However, if swimmers receive appropriate muscle conditioning with an effective training method to increase  $VO_2\text{max}$ , research suggests that  $VO_2\text{max}$  is significantly related to swimming performance at various distances [5]. Therefore, efficient swimming performance is measured by the time athletes spend in competition [2, 26]. This study is expected to provide useful information for improving  $VO_2\text{max}$  and body composition, which are important factors in increasing swimming efficiency. The objective of this study was to evaluate the effectiveness of a six-week core muscle high-intensity interval training regimen on  $VO_2\text{max}$ , vital capacity, and body composition in male swimmers.

## Materials and Methods

### *Participants*

Twenty male swimmers from Roi Et Rajabhat University who trained regularly participated in this study. They were randomly divided into two groups using a randomized controlled research design. Participants were randomly assigned to either an experimental group performing core muscle high-intensity interval training (CM-HIIT) (n=10) or a control group following a normal program (n=10). The inclusion criteria for this study were that the participants had no musculoskeletal injuries that would affect their participation in the program and had at least one year of competitive experience. The exclusion criteria were that the participants

sustained injuries and could not continue their participation. All participants were fully informed of the testing and data collection procedures before the intervention and gave their written consent to participate in this study. This study was approved by the Ethics Committee of Rajamangala University of Technology Isan (No. HEC-01-65-015) and followed the guidelines of the Declaration of Helsinki. The anthropometric data of swimmers at baseline are detailed in Table 1.

**Table 1.** Baseline Anthropometric Data of Swimmers

Variable	Experimental group (n = 10)	Control group (n = 10)
Age (yrs)	21.1 ± 0.84	20.4 ± 0.70
Weight (kg)	76.67 ± 15.47	73.00 ± 18.49
Height (m)	1.71 ± 0.05	1.74 ± 0.05
Body Composition (kg/m <sup>2</sup> )	25.19 ± 5.00	24.99 ± 6.42

### *Procedures*

Participants in the high-intensity interval training group were asked to complete 18 sessions, training three days per week for six weeks, with each session lasting 50 minutes (10-minute warm-up, 30-minute main training, and 10-minute cool-down). Both the experimental and control groups underwent the YMCA submaximal cycle test to assess  $VO_2\text{max}$ , vital capacity assessment using a spirometer [27], and body composition analysis using a bioelectrical impedance analyzer (InBalance 300).

### *Training Protocol*

The experimental group in this study received a CM-HIIT intervention consisting of six core exercises (flutter kicks, single-leg V-ups, trunk extension, alternating-arm Russian twist, plank-to-push-up, and bird dog) [28, 29, 22], performed at maximum speed. The training protocol was conducted for 18 sessions over six weeks (three times per week, 50 minutes per session), as shown in Table 2.

### *Measurements*

All participants in this study underwent three assessments of body composition, lung function, and  $VO_2\text{max}$ : before, after week four, and after week six. All tests were performed sequentially and under the supervision of the investigators throughout the testing.

### *Body composition assessment*

Body composition assessment in this study was performed using a bioelectrical impedance analyzer (InBalance 300). Participants removed their shoes and stood still in the designated foot positions on the device for approximately 20 seconds. Body weight (kg), body mass index (BMI), body fat percentage (%), fat mass (kg), and muscle mass (kg) were recorded.

**Table 2.** Core muscle-high intensity interval training

Week	Exercises: 1. Flutter kicks 2. Single leg V-ups 3. Trunk extension 4. Alternating arm Russian twist 5. Plank to push up 6. Bird dog	
<b>1 - 2</b>  15*6*15*30	1. 	4. 
<b>3 - 4</b>  20*6*10*45	2. 	5. 
<b>5 - 6</b>  30*6*15*30	3. 	6. 

Note. Repetition (second)\*Sets\*Rest/set (second)\*Rest/exercises (second)

#### Lung function

In this experiment, a spirometer was used to test lung function efficiency [27], consisting of three parameters:

1. The maximum volume of air that can be inhaled and exhaled rapidly and forcefully (forced vital capacity, FVC);
2. The volume of air expelled in the first second of rapid and forceful expiration (forced expiratory volume in one second, FEV<sub>1</sub>);
3. The volume of air from full inhalation and exhalation in one minute (maximum voluntary ventilation, MVV).

The subjects were asked to take two to three normal breaths, then take a full breath and blow out forcefully and quickly until all the air was exhaled. For MVV, the subjects were asked to take deep and fast breaths in and out as much as possible within 15 to 20 seconds.

#### Maximum oxygen consumption

This study used the YMCA submaximal cycle test (VO<sub>2</sub>max) to assess aerobic capacity and predict maximal oxygen uptake [30]. The YMCA cycle ergometer test estimates VO<sub>2</sub>max by monitoring heart rate for two to three minutes at a submaximal workload and calculating the maximum heart rate (Max HR) (220 – age) to determine the work rate. The test was conducted by cycling for two to four periods with increasing resistance. Each period lasted three minutes, and heart rate was recorded in the last 30 seconds of each period. The test was considered complete when the heart rate was between 110 and 150 bpm (85% Max HR) in at least two workload periods, with each period increasing in intensity based on the heart rate after the first period.

#### Statistical Analysis

Data analysis of all outcomes in this study was performed using IBM SPSS Statistics version 22.0 for Windows (SPSS Inc., 2010, IBM Corp., Armonk, NY). All data are presented as mean ± standard deviation. After the Shapiro-Wilk test to determine the normal distribution of the sample data, differences in maximal oxygen uptake, lung function, and body composition were tested using a two-way ANOVA with repeated-measures analysis of variance (2 groups × 3 time points: before, after week four, and after week six) with a significance level of 0.05.

#### Results

##### Maximal Oxygen Consumption

The results for Max HR and VO<sub>2</sub>max are presented in Tables 3 and 4. There was a group × time interaction. In the experimental group, Max HR significantly decreased after four and six weeks compared to baseline (Table 3). VO<sub>2</sub>max significantly increased after four and six weeks, with a greater improvement observed at six weeks compared to four weeks (Table 3).

In the control group, Max HR also significantly decreased over time, although the reduction was less pronounced compared to the experimental group (Table 4). However, VO<sub>2</sub>max significantly decreased after six weeks compared to baseline in both groups (Table 4). Resting HR did not show significant differences between time points.

##### Lung Function

Vital capacity significantly increased in both groups over time (Tables 3 and 4). In the experimental group, it showed a steady improvement after four and six weeks, with a greater increase observed

at six weeks (Table 3). In the control group, vital capacity also increased significantly, though the improvement was less pronounced (Table 4). When compared between groups, vital capacity was significantly different after six weeks ( $p < 0.05$ ).

*Body Composition*

Body composition data are presented in Tables 3 and 4. Significant group  $\times$  time interactions were observed in body weight, body mass index, body fat percentage, fat mass, and muscle mass (Tables 3 and 4). In the experimental group, body weight, body fat percentage, and fat mass significantly decreased after six weeks, while muscle mass increased (Table 3). In contrast, in the control group, body fat percentage and fat mass significantly decreased, but no significant changes were observed in body weight, BMI, or muscle mass (Table 4).

**Discussion**

This study was conducted to investigate the effectiveness of a six-week core muscle high-intensity interval training regimen on  $VO_{2max}$ , vital capacity, and body composition. In this study, male swimmers showed significant increases in  $VO_{2max}$ , lung function, and muscle mass, as well as significant decreases in body mass index, body fat percentage, and fat mass after six weeks of core muscle high-intensity interval training.

*VO<sub>2</sub>max and Lung Function*

From the results of CM-HIIT, it can be seen that the experimental and control groups had significantly different decreases in Max HR and  $VO_{2max}$  after six weeks in both groups, but no significant difference in resting HR was found after

**Table 3.** The variable of the experimental groups

Variables	Experimental group (n = 10)		
	Before	4 Weeks	6 Weeks
<b>Maximal Oxygen Consumption</b>			
Resting HR (beats/min)	79.40 $\pm$ 10.89	79.80 $\pm$ 8.28	77.10 $\pm$ 8.29
Max HR (beats/min)	165.70 $\pm$ 17.71	156.80 $\pm$ 12.14*†	153.80 $\pm$ 11.01*†
Vo2max (ml/kg/min)	29.75 $\pm$ 10.99	33.84 $\pm$ 9.80*	38.77 $\pm$ 10.84***
<b>Vital Capacity</b>			
Vital capacity (cc/kg)	59.05 $\pm$ 13.42	65.69 $\pm$ 10.56*	67.93 $\pm$ 11.57***†
<b>Body Composition</b>			
Body Weight (kg)	76.67 $\pm$ 15.47	75.89 $\pm$ 14.18	75.05 $\pm$ 14.50***
Body Mass Index (kg/m <sup>2</sup> )	25.19 $\pm$ 5.00	24.93 $\pm$ 4.53	24.66 $\pm$ 4.66**
Body fat percentage (%)	23.79 $\pm$ 8.28	22.43 $\pm$ 9.18*	21.64 $\pm$ 9.17**
Fat mass (kg)	19.09 $\pm$ 10.24	18.09 $\pm$ 10.19*	17.56 $\pm$ 10.12**
Muscle mass (kg)	53.25 $\pm$ 5.37	53.92 $\pm$ 5.00	54.72 $\pm$ 4.85*

Note. Significant difference from before, \* $p < 0.05$ ; week 4, \*\* $p < 0.05$ ; between groups, † $p < 0.05$

**Table 4.** The variable of the control groups

Variables	Control group (n = 10)		
	Before	4 Weeks	6 Weeks
<b>Maximal Oxygen Consumption</b>			
Resting HR (beats/min)	79.90 $\pm$ 13.16	78.10 $\pm$ 11.69	75.50 $\pm$ 11.11
Max HR (beats/min)	175.2 $\pm$ 16.16	167.90 $\pm$ 12.41*	163.20 $\pm$ 10.77*
Vo2max (ml/kg/min)	31.45 $\pm$ 6.70	30.47 $\pm$ 11.32	34.81 $\pm$ 7.02*
<b>Vital Capacity</b>			
Vital capacity (cc/kg)	55.56 $\pm$ 11.64	59.28 $\pm$ 13.31*	58.98 $\pm$ 10.29*
<b>Body Composition</b>			
Body Weight (kg)	73.00 $\pm$ 18.49	71.80 $\pm$ 18.58	72.34 $\pm$ 17.29
Body Mass Index (kg/m <sup>2</sup> )	24.99 $\pm$ 6.42	24.58 $\pm$ 6.51	24.77 $\pm$ 6.10
Body fat percentage (%)	21.92 $\pm$ 10.58	19.67 $\pm$ 10.16*	21.80 $\pm$ 9.91**
Fat mass (kg)	17.58 $\pm$ 12.75	15.74 $\pm$ 12.47*	17.11 $\pm$ 11.90**
Muscle mass (kg)	51.58 $\pm$ 6.95	50.23 $\pm$ 10.69	51.44 $\pm$ 6.53

Note. Significant difference from before, \* $p < 0.05$ ; week 4, \*\* $p < 0.05$ ; between groups, † $p < 0.05$

four weeks and six weeks. When compared between the groups, it can be seen that in the experimental group that received HIIT, after four and six weeks, Max HR decreased significantly more than in the control group ( $p < 0.05$ ). However, when comparing the  $VO_2\text{max}$  values in the experimental group, it was found that  $VO_2\text{max}$  increased by  $\sim 4.09\text{--}9.02$  ml/kg/min, with an increase of  $\sim 4.09$  ml/kg/min after four weeks and  $\sim 9.02$  ml/kg/min after six weeks compared to baseline. Additionally, after six weeks,  $VO_2\text{max}$  increased by  $\sim 4.93$  ml/kg/min compared to four weeks. In the control group,  $VO_2\text{max}$  increased after six weeks by  $\sim 3.64$  ml/kg/min compared to baseline, indicating that the group that received three days per week of high-intensity core training combined with a conventional swimming program for six weeks had better  $VO_2\text{max}$  than the control group that followed a conventional swimming program alone.

Previous studies have shown that a group that received short bursts of rapid muscle training three days per week can stimulate the work level to at least 90% of  $VO_2\text{max}$ , resulting in a 9.6% increase in  $VO_2\text{max}$  efficiency, which is higher than in the control group that trained only in swimming [9, 21, 4]. At the same time, the increase in  $VO_2\text{max}$  in both groups, as presented in this study, shows a significant improvement in lung function, as indicated by the vital capacity test results after four and six weeks ( $p < 0.05$ ). Previous studies have consistently shown that CM-HIIT improves  $VO_2\text{max}$ , lung function, and cardiovascular endurance significantly [27, 31, 32]. The efficiency of these improvements depends on the coordination of the cardiovascular and respiratory systems, which is influenced by the processes of anaerobic and aerobic respiration during HIIT, leading to enhanced fitness levels [33, 34] (referring to [35]). Meanwhile,  $VO_2\text{max}$  is considered a physiological variable that reflects cardiovascular system efficiency [34] (referring to [36, 37]). When athletes are trained at an appropriate intensity, leading to the activation of the nervous system, the strength of the respiratory muscles improves,  $VO_2\text{max}$  increases, and lung function efficiency significantly improves [38, 39, 37, 40]. The data from this study demonstrate that high-intensity interval training performed at an appropriate intensity and targeting core muscles involved in swimmer movements can improve maximal oxygen consumption in a shorter period compared to previous studies.

#### *Body Composition*

After receiving 18 sessions of CM-HIIT, it was found that the experimental group had significantly decreased body fat percentage and fat mass after four and six weeks compared to baseline ( $p < 0.05$ ). In the control group, which did not receive HIIT training, body fat percentage and fat mass also

significantly decreased after four weeks compared to baseline and after six weeks compared to four weeks ( $p < 0.05$ ). This is consistent with previous studies reporting similar results after four weeks of training in football players [18], female ice hockey players [41], and healthy male individuals [15], as well as after eight weeks in field hockey players [20] and handball athletes [42, 19], showing that the HIIT training pattern resulted in a significant decrease in body fat percentage and fat mass ( $p < 0.05$ ).

The continuous training pattern that athletes normally follow may result in higher-intensity muscle work, which can help stimulate the metabolic rate during training and reduce body fat percentage and fat mass. Murawska-Ciałowicz et al. [43] stated that the reduction in body fat due to intensive training allows muscles to work continuously at an appropriate level, increasing the basal metabolic rate. Similarly, Mohammad et al. [42] and Tahir & Muhammed [18] pointed out that an appropriate HIIT training pattern improves physical fitness and allows athletes to lose weight and BMI, helping to reduce body fat.

Regarding the body composition results showing statistically significant changes only in the experimental group, it was reported that muscle mass significantly increased after six weeks compared to baseline. This may be due to the appropriate high-intensity interval training pattern used in this study, which was intense enough to stimulate muscular adaptation at a high level. Such high-intensity endurance training improves neuromuscular function, leading to enhanced muscle strength and function [44]. However, it has been shown that HIIT at appropriate levels can increase muscle mass in athletes [42, 18].

This increase in muscle mass can be explained by the stimulation of concentric and eccentric muscle contractions induced by high-intensity training, which enhances muscle protein synthesis and leads to muscle fiber hypertrophy [45]. Although both regular swimming and high-intensity interval training can stimulate metabolic rate and decrease body fat percentage and fat mass in swimmers, the present data show that after six weeks, swimmers who received high-intensity interval training had increased muscle mass, resulting in more efficient muscle function than those who followed only a conventional swimming program.

The findings of this study suggest that a six-week core muscle high-intensity interval training (CM-HIIT) program effectively enhances  $VO_2\text{max}$ , lung function, and body composition in male swimmers. The observed improvements in cardiorespiratory fitness and body composition highlight the potential of HIIT-based core training as a valuable supplement to conventional swimming programs. Future research should consider a larger sample size, a longer intervention period, and controlled

dietary factors to enhance the robustness of findings and further explore the long-term physiological adaptations associated with HIIT-based core training in swimmers.

#### *Limitations of the Study*

This study has some limitations. First, the sample size was relatively small, consisting of only twenty male swimmers, which may limit the generalizability of the findings to broader athletic populations. Second, the study duration was six weeks, which may not fully capture the long-term effects of CM-HIIT on  $\text{VO}_2\text{max}$ , lung function, and body composition. Third, the study did not control for dietary intake, which could influence body composition changes. Finally, the participants' individual training loads outside of the study protocol were not monitored, which may have affected the results. Future research should consider a larger sample size, a longer intervention

period, and controlled dietary factors to enhance the robustness of findings.

#### **Conclusions**

Maximum oxygen consumption, lung function, and body composition in swimmers improved after six weeks of core muscle high-intensity interval training (CM-HIIT). These adaptations resulted in physiological changes, enhanced cardiovascular fitness, and improved body composition in trained swimmers, all of which are important for swimming performance. However, coaches and trainers must carefully consider training intensity and program design to optimize maximal oxygen uptake while ensuring athlete safety and performance efficiency.

#### **Conflict of Interest**

The authors report that there are no competing interests to declare.

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